Toward data anomaly detection for automated structural health monitoring: Exploiting generative adversarial nets and autoencoders

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Abstract

Damage detection is one of the most important tasks for structural health monitoring of civil infrastructure. Before a damage detection algorithm can be applied, the integrity of the data must be ensured; otherwise results may be misleading or incorrect. Indeed, sensor system malfunction, which results in anomalous data (often called faulty data), is a serious problem, as the sensors usually must operate in extremely harsh environments. Identifying and eliminating anomalies in the data is crucial to ensuring that reliable monitoring results can be achieved. Because of the vast amounts of data typically collected by a structural health monitoring system, manual removal of the anomalous data is prohibitive. Machine learning methods have the potential to automate the process of data anomaly detection. Although supervised methods have been proven to be effective for detecting data anomalies, two unresolved challenges reduce the accuracy of anomaly detection: (1) the class imbalance and (2) incompleteness of anomalous patterns of training dataset. Unsupervised methods have the potential to address these challenges, but improvements are required to deal with vast amounts of monitoring data. In this article, the generative adversarial networks are combined with a widely applied unsupervised method, that is, autoencoders, to improve the performance of existing unsupervised learning methods. In addition, the time-series data are transformed to Gramian Angular Field images so that advanced computer vision methods can be included in the network. Two structural health monitoring datasets from a full-scale bridge, including examples of anomalous data caused by sensor system malfunctions, are utilized to validate the proposed methodology. Results show that the proposed methodology can successfully identify data anomalies with good accuracy and robustness, hence can overcome one of the key difficulties in achieving automated structural health monitoring.